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ABSTRACT

This manual was prepared for the student who plans to enter the machine shop field. The 20 selected jobs provide the student with knowledge and step-by-step procedures for the operation of milling machines. The text is organized so that each job has an objective, tools needed, step-by-step instructions, a progress quiz, and space for reference, thereby allowing each student the opportunity to study the steps and the progress quiz before starting work on a machine. The entire organization is designed to help the teacher work efficiently in teaching each individual student. A sample progress chart is provided to help the teacher keep a record of the jobs performed by each student, the grade, and the degree of progress for each job. Five major categories are included: Horizontal Milling Machine (Principal Parts of a Milling Machine, Milling Machine Cutters, Use of Selected Cutters, and Milling Machine Setups), Horizontal Milling Machine Projects (14 jobs), Vertical Milling Machine (Cutters and Principal Parts), Vertical Milling Machine Projects (6 jobs), and Review of Milling Machines. (HD)

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State of New Jersey
Department of Education
Division of Vocational Education

MACHINE SHOP OPERATIONS -- 2

Milling Machine, Heat Treatment of Metals, and Grinders

Joseph Currao, Machine Shop Instructor
Louis Usarzewicz, Drafting Instructor

Herman Purdie, Director
Bayonne High School - Vocational Division
Bayonne, New Jersey

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TO THE STUDENT

This book was prepared for the student who plans to enter the Machine Shop field. The selected jobs provide you with the knowledge and step-by-step procedures for the operation of milling machines. It is important for you to lay your work out quickly and accurately in order to meet shop standards.

SAFETY

Safety is very important in the Machine Shop. Safety glasses, shoes, and clothing should be worn at all times. If safety rules are not carried out, a worker could be injured in a second. This list will help you become a safe worker.

SAFETY PRECAUTIONS

1. Switch the machine to off when oiling it.
2. Never lean against the machine.
3. Don't allow anyone to work or fool around the machine when you are oiling it.
4. Wipe off oil which drips from the oil cup after oiling.
5. Never walk away from the machine while it is in motion.
6. Avoid pushing in the shop.
7. Always brush chips away when the machine is off.

TO THE TEACHER

Students need step-by-step instructions and discussion questions, but they also need to know how they are progressing. The sample Progress Chart on the next two pages provides a record of the jobs performed by each student. The teacher can provide a check mark for completion, a grade for quality, or some other symbol showing degree of progress for each job.

This text is organized so that each job has an objective, tools needed, step-by-step instructions, space for reference. This organization allows each student the opportunity to study the steps and the progress quiz before starting work on a machine. Space has been left for the teacher to assign the references available in the local classroom; this text can be used with any number of different references. The entire organization is designed to help the teacher work efficiently in teaching each individual student.

Horizontal Milling
Milling Machine Operations
Vertical Milling
Student's Name
Periods
1 A
1 B
1 C
2
3
4
5
6
7
8
9 A
9 B
9 C
10
11
12
1
2
3
4
5
6

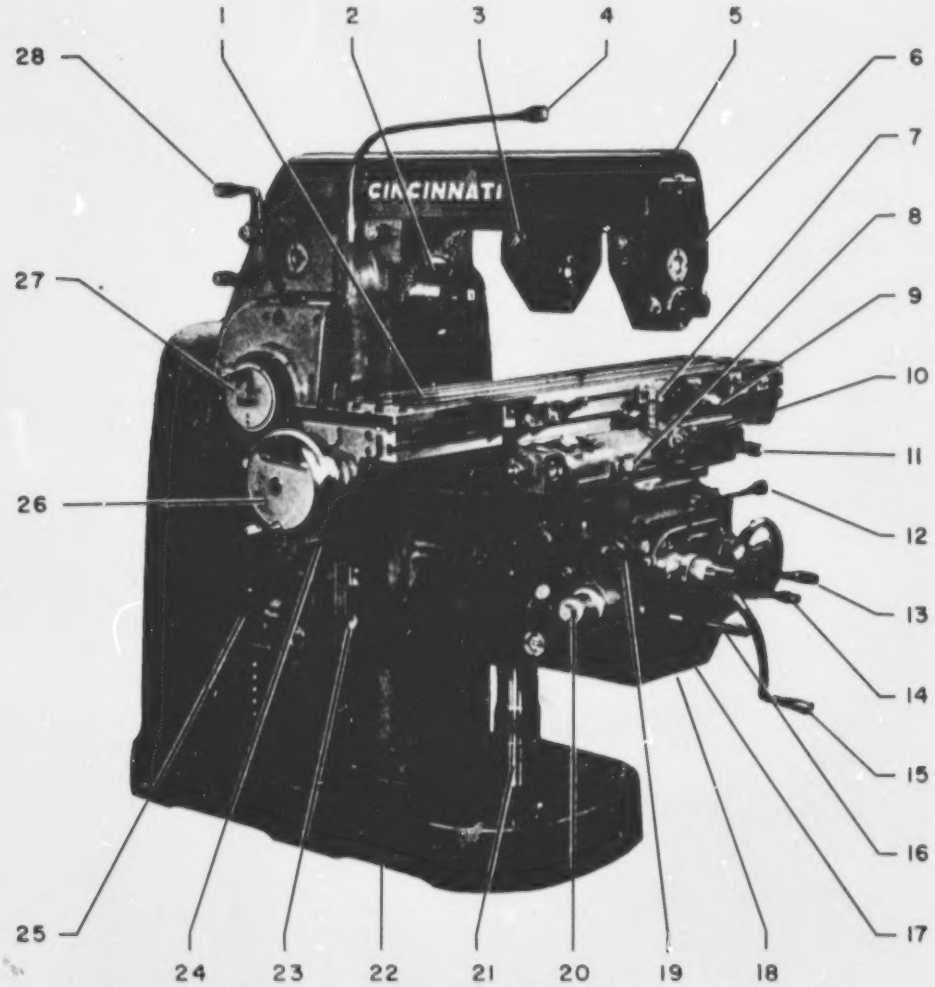
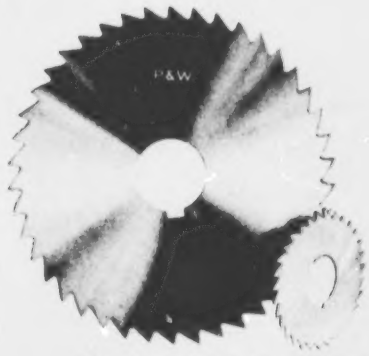


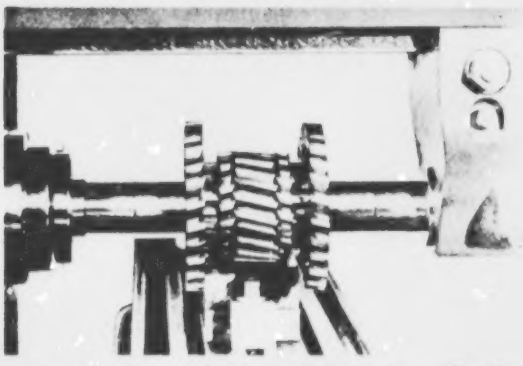
FIG. 10-1. Nomenclature of plain knee-and-column milling machine, front view. (Cincinnati Milling Machine Co.)

1. Table
2. Arbor-loc spindle nose
3. Outer arbor support
4. Start-stop lever
5. Overarm
6. Inner arbor support
7. Table trip plunger
8. Blacklash eliminator knob
9. Table trip dogs
10. Saddle
11. Table-feed lever
12. Cross-feed lever
13. Rapid traverse lever
14. Cross-feed handwheel
15. Vertical-feed handcrank
16. Feed change crank
17. Feed change dial
18. Knee
19. Vertical-feed lever
20. Knee oil filter
21. Telescopic cutting-fluid return
22. Base
23. Vertical trip dogs
24. Knee clamp
25. Column
26. Table traverse handwheel
27. Speed change dial and crank
28. Overarm positioning crank

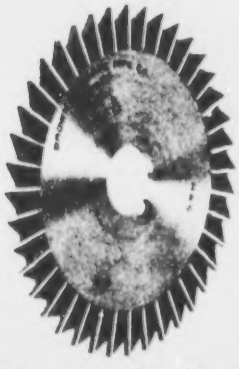
Staggered-tooth side-milling cutter. (Union Twist Drill Co.)



Slitting saws. (Pratt & Whitney Co.)



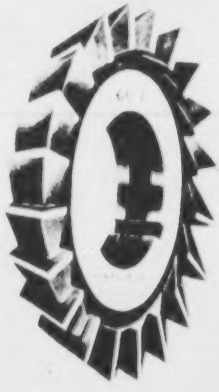
Form milling with seven cutters. (The Cincinnati Milling Machine Co.)



Slitting saws with side chip clearance. (Brown & Sharpe Mfg. Co.)

Face-milling cutter with inserted teeth. (Brown & Sharpe Mfg. Co.)

Angular cutter. (Union Twist Drill Co.)

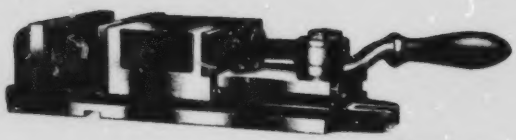


1. Face Milling Cutters -- May be used on either horizontal or vertical machines.

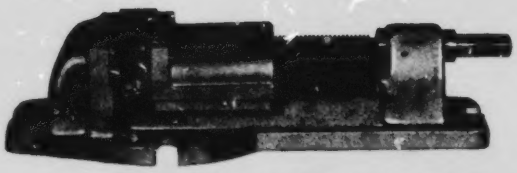
2. Peripheral Milling Cutters -- Commonly used for machining flat surfaces, sawing, and grooving.

3. Form Cutters -- Standard and available from stock. Special forms can be made to suit any particular job required.

4. Angle Cutters -- Used to cut teeth in ratchet wheels, for milling dovetails, etc. The straight side is provided with teeth to give a better finish with this side when cutting grooves.

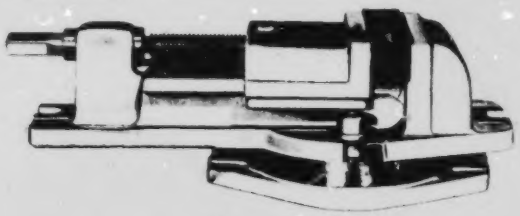


Plain vise. (The Cincinnati Milling Machine Co.)

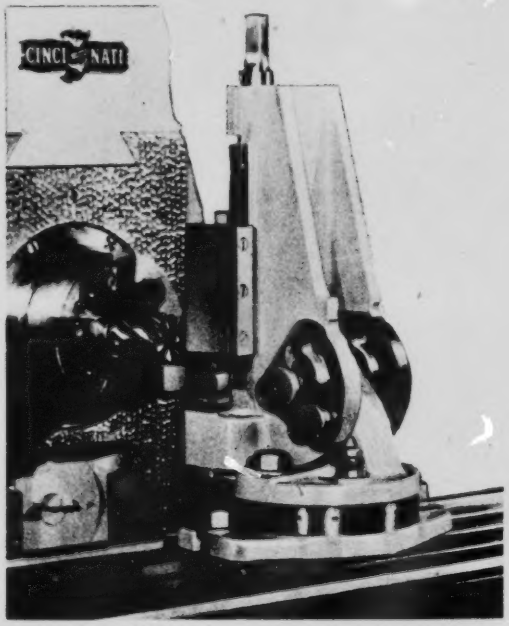


The flanged vise. (The Cincinnati Milling Machine Co.)

The swivel vise. (The Cincinnati Milling Machine Co.)



The toolmakers' universal vise. (The Cincinnati Milling Machine Co.)



Several methods are used in holding the work on the machine table. Before making any setup, you must make sure the table is clean with no chips lying around. The machinist must know the setup required to do certain jobs.

Devices Used in Milling Machine Setup

1. Swivel Vise -- Vise body that can be swiveled to any required angle.

2. Plain Vise -- Mounted on the table and is lower than the swivel type.

3. Toolmaker's Universal Vise -- Use particularly suited for toolroom work.

4. Flanged Vise -- Holds work to 7" wide and is the type used for plain milling operations. Its low height and broad base give it the rigidity needed for heavy cuts.

HORIZONTAL MILLING MACHINE PROJECT JOB NO. 1A, 1B, and 1C

PLAIN MILLING

OBJECTIVE: Be able to mill a piece of work so all sides are parallel to each other.

STOCK: C.I. (cast iron)

TOOLS: Vise (plain), scale, file, coarse tooth cutter, 1/4" cutter, 1" cutter, and double end cutter.

STEPS:

1. Cut piece 2-5/8" x 2-7/8".
2. Place in vise and mill to size as in Drawing No. 1A.
3. Remove cutter and put 1/4" cutter on arbor.
4. Mill to size as in Drawing No. 1B.
5. Remove cutter and put 1" cutter on arbor.
6. Mill to size as in Drawing No. 1B.
7. Remove cutter and put 1" cutter on arbor.
8. Mill to size as in Drawing No. 1C.
9. Remove burrs, and have Instructor check job.

PROGRESS QUIZ:

1. State the difference between a coarse cutter and a plain cutter.
2. State the difference between a vertical and horizontal milling machine.
3. State the difference between a plain vise and a toolmakers vise.
4. Why should a cutter be placed on a wooden board when not in use?

5. Why should a milling machine cutter be handled with a rag?

6. Write a Job Operation Sheet for Job No. 1A, 1B, and 1C.

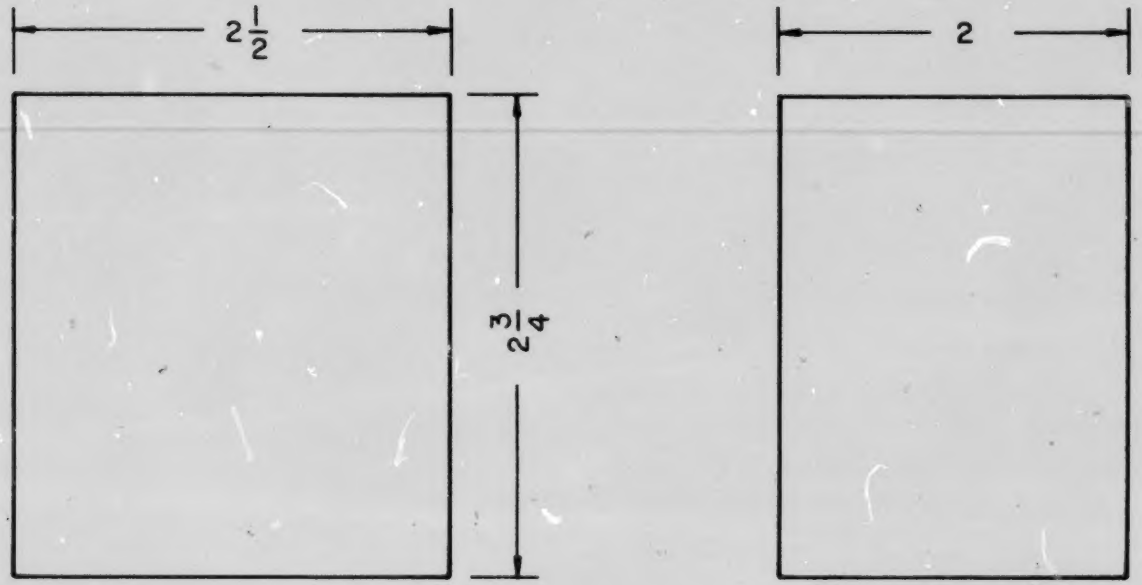
REFERENCES:

MACHINE OPERATIONS

HORIZONTAL MILLING

JOB NO. 1A

PLAIN MILLING



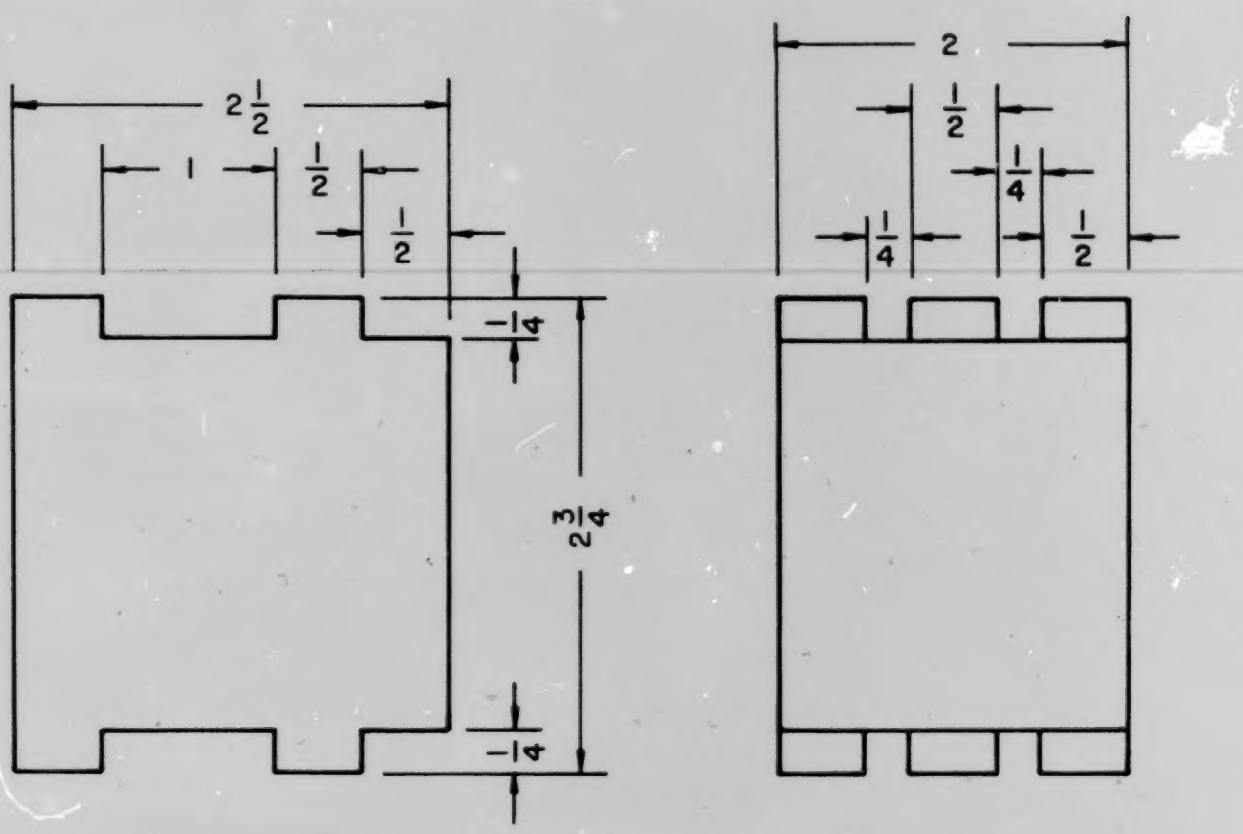
SCALE: 1"=1"

MACHINE OPERATIONS

HORIZONTAL MILLING

JOB NO. 1B

PLAIN MILLING



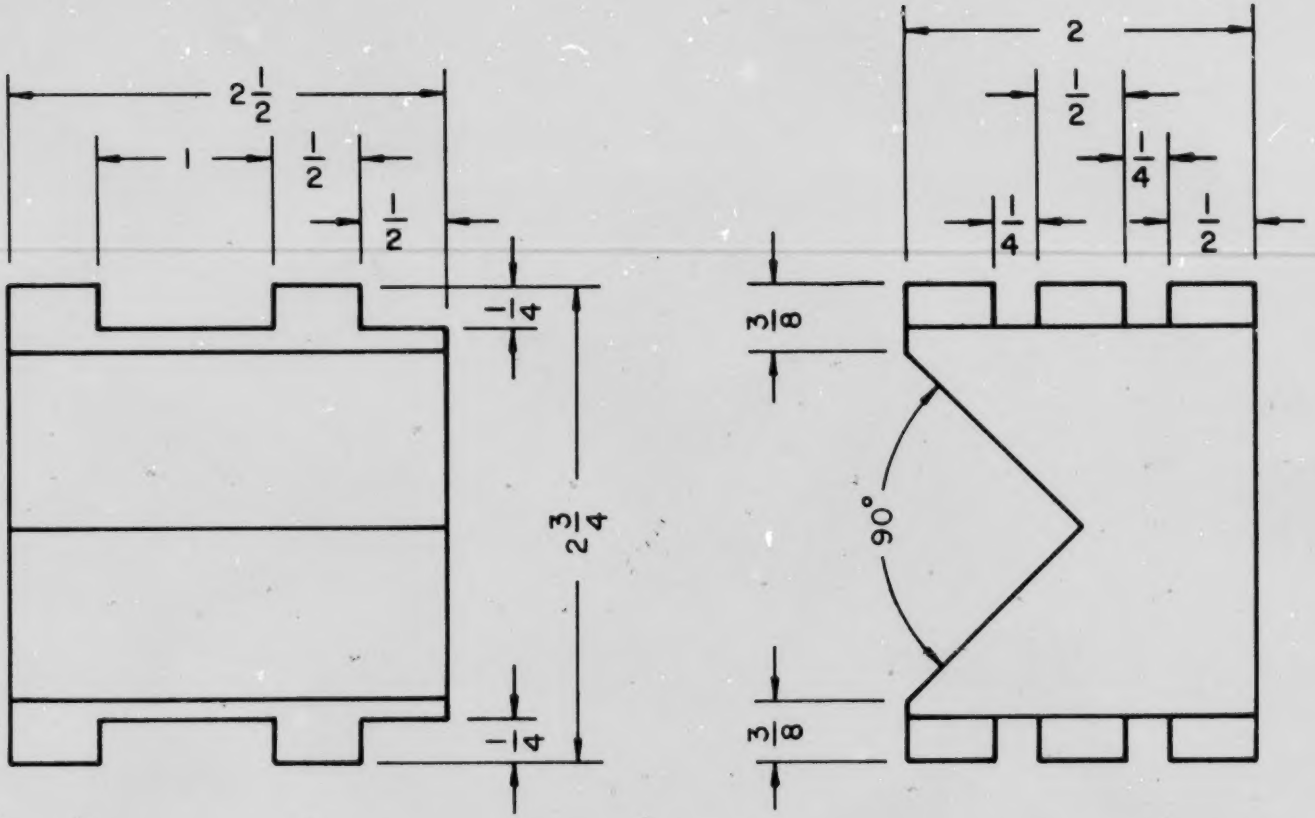
SCALE: 1" = 1"

MACHINE OPERATIONS

HORIZONTAL MILLING

JOB NO.IC

PLAIN MILLING



SCALE: 1" = 1"

HORIZONTAL MILLING MACHINE PROJECT JOB NO. 2

SIDE MILLING
(Step Milling)

OBJECTIVE: Be able to use a side milling cutter.

STOCK: C.I. (Cast iron)

TOOLS: Vise -- 1½" wide cutter.
1" side cutter.
1" depth gage, file.

STEPS:

1. Clamp in vise.
2. Mill to 1.125 dimension in 3 cuts -- 1st cut .145 deep, 2nd cut .145 deep, and finish cut .022" deep.
3. Remove cutter and replace it with 1" wide cutter.
4. Reset work in vise so that the 4" dimension runs parallel to the milling arbor and the cutter mills across the 1-7/16" dim.
5. Mill 1st step to 1" wide x .250 deep to .875 dim. in 3 cuts.
6. Mill 2nd step to 1" wide x .250 deep to .625 dim. in 3 rough cuts and 1 finish cut.
7. Mill 3rd step to 1" wide x .250" deep to .375 dim. in 4 roughing cuts and 1 finish cut. Measure steps with depth micrometer.
8. Remove work and file off burrs. Inspect.

PROGRESS QUIZ:

1. Explain the difference between the plain cutter and the side milling cutter.
2. Why was a depth micrometer used instead of a scale?
3. In milling the steps, why were 3 cuts taken instead of 1 cut?
4. What safety precaution was used in handling the cutter?

5. What is the difference between conventional and climb milling?

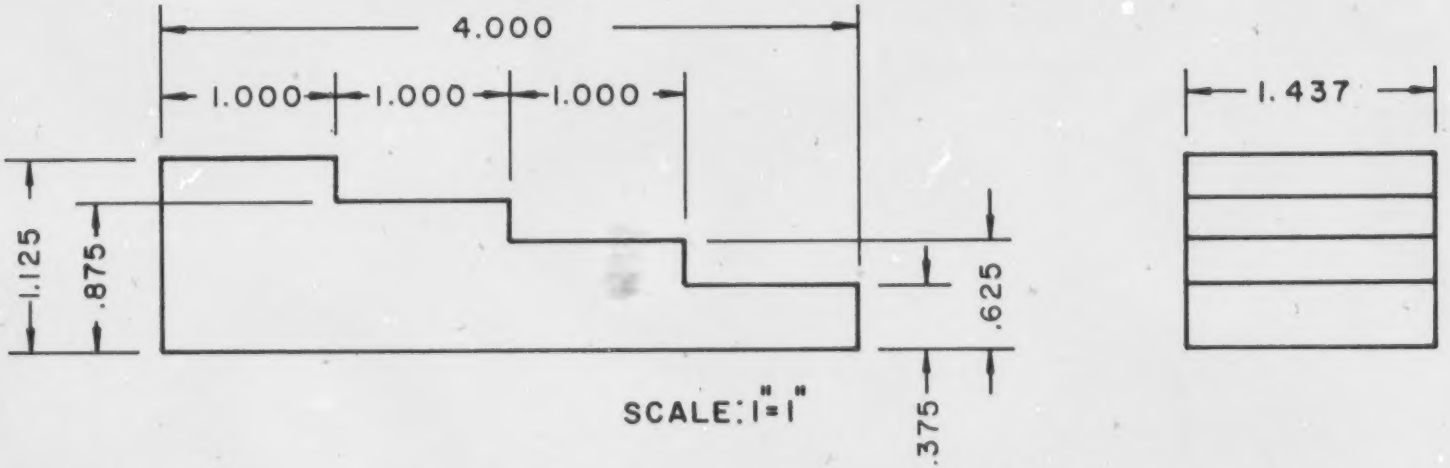
REFERENCES:

MACHINE OPERATIONS

HORIZONTAL MILLING

JOB NO. 2

SIDE MILLING



HORIZONTAL MILLING MACHINE PROJECT JOB NO. 3

ANGLE MILLING

OBJECTIVE: Be able to review angle milling.

STOCK: Cast Iron or machine steel.

TOOLS: Vise, angle cutter (45^{o}), file, and protractor.

STEPS:

1. Cut off 3/4" x 1" x 6-1/8" stock.
2. Mill off ends to 6" dia.
3. Mill the 45^{o} angle to dimension.
4. Mill the V to dimensions the full length of the piece.
5. Remove burrs and inspect.

PROGRESS QUIZ:

1. What was the purpose of using a double-angle cutter instead of a single-angle cutter?
2. What type of vise was used on this job?
3. What type of milling was done -- convention or climb? Give reasons for your answer.
4. What instrument was used to check the vise for straightness?
5. Name 3 ways of checking the vise for accuracy.

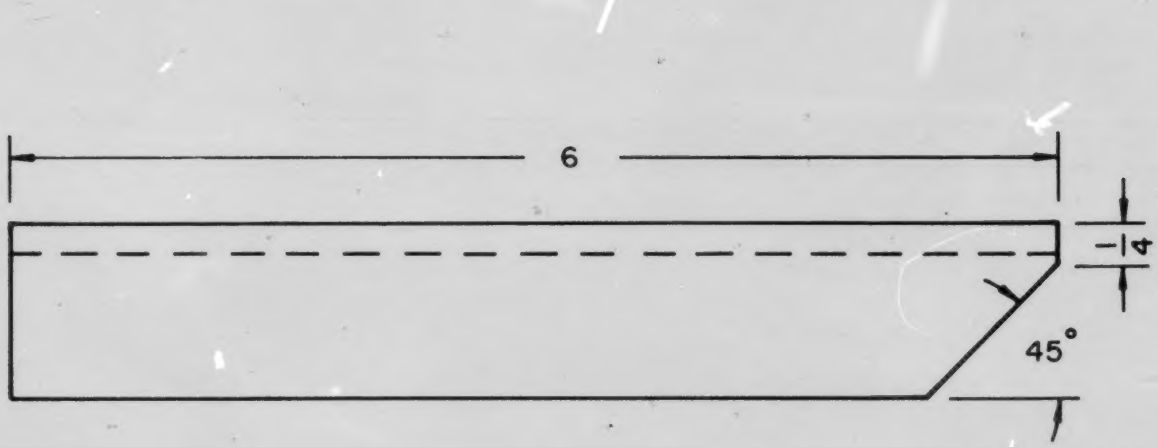
REFERENCES:

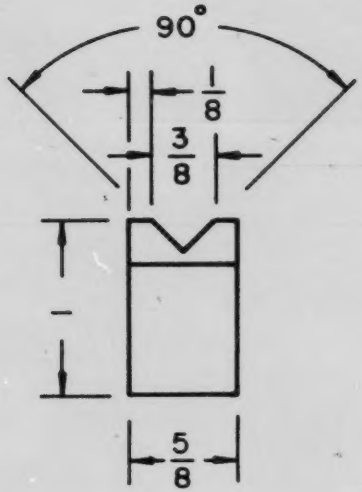
MACHINE OPERATIONS

HORIZONTAL MILLING

JOB NO. 3

ANGLE MILLING





SCALE: 1" = 1"

HORIZONTAL MILLING MACHINE PROJECT JOB NO. 4

PLAIN AND ANGLE MILLING

OBJECTIVE: Be able to mill angle using a plain cutter.

STOCK: C.I. (Cast iron)

TOOLS: Vise, scriber, bevel protractor, 1/8" saw 3" dia., 3/4" cutter, 4" dia. file, and 2" micrometer.

STEPS:

1. Lay out the V on three sides 5/16" from end.
2. Mill V on 3 sides of the piece.
3. Mill 1/8" slots on 3 sides of the piece.
4. Mill slot to size on drawing.
5. Remove all burrs.
6. Have instructor inspect piece.

PROGRESS QUIZ:

L. Explain why a plain cutter was used instead of an angle cutter.
2. What is the purpose of steel ink?
3. What do you mean by a 90^{o} cutter and a 60^{o} cutter?
4. How was the vise lined with the machine?
5. Why should a wooden board be available around the machine?

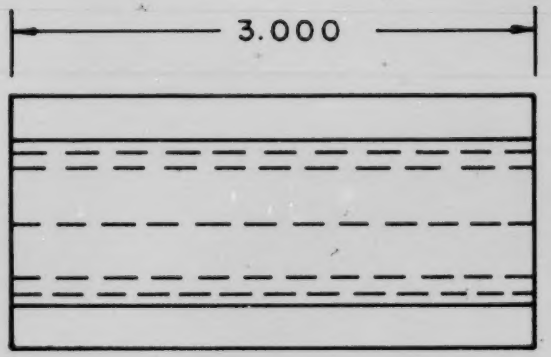
REFERENCES:

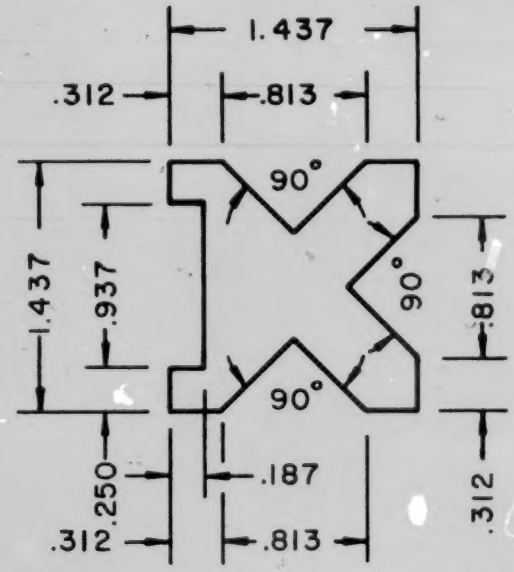
MACHINE OPERATIONS

HORIZONTAL MILLING

JOB NO.4

PLAIN- ANGLE MILLING





SCALE: 1"=1"

HORIZONTAL MILLING MACHINE PROJECT JOB NO. 5

KEYWAY MILLING

OBJECTIVE: Be able to mill a standard keyway and a Woodruff keyway on a shaft.

STOCK: C.D.S.

TOOLS: Vise (swivel), 1/4" cutter, Woodruff cutter, depth micrometer, and square file.

STEPS:

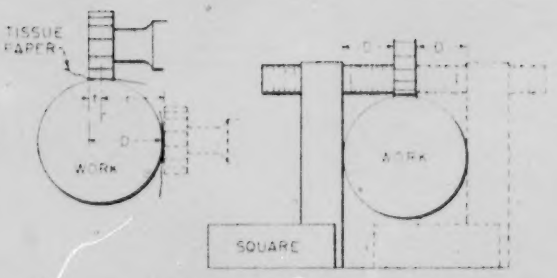
1. Vise must be straight.
2. Scribe 4 lines 90° apart on face of shaft.
3. Mill keyway (straight) 1/4" x 1/8" deep 2" long.
4. Remove cutter and arbor from machine.
5. Insert Woodruff cutter in adapter.
6. Turn shaft 180° to mill Woodruff keyway.
7. Mill keyway.
8. File burr and have shaft inspected by instructor.

PROGRESS QUIZ:

1. When is a standard keyway used?
2. When is a Woodruff keyway used?
3. Why do we scribe 4 lines on the face of the shaft?
4. How is the center of the shaft located?
5. State the accurate way of finding the center of the shaft.

REFERENCES:

HOW TO SET UP THE CUTTER



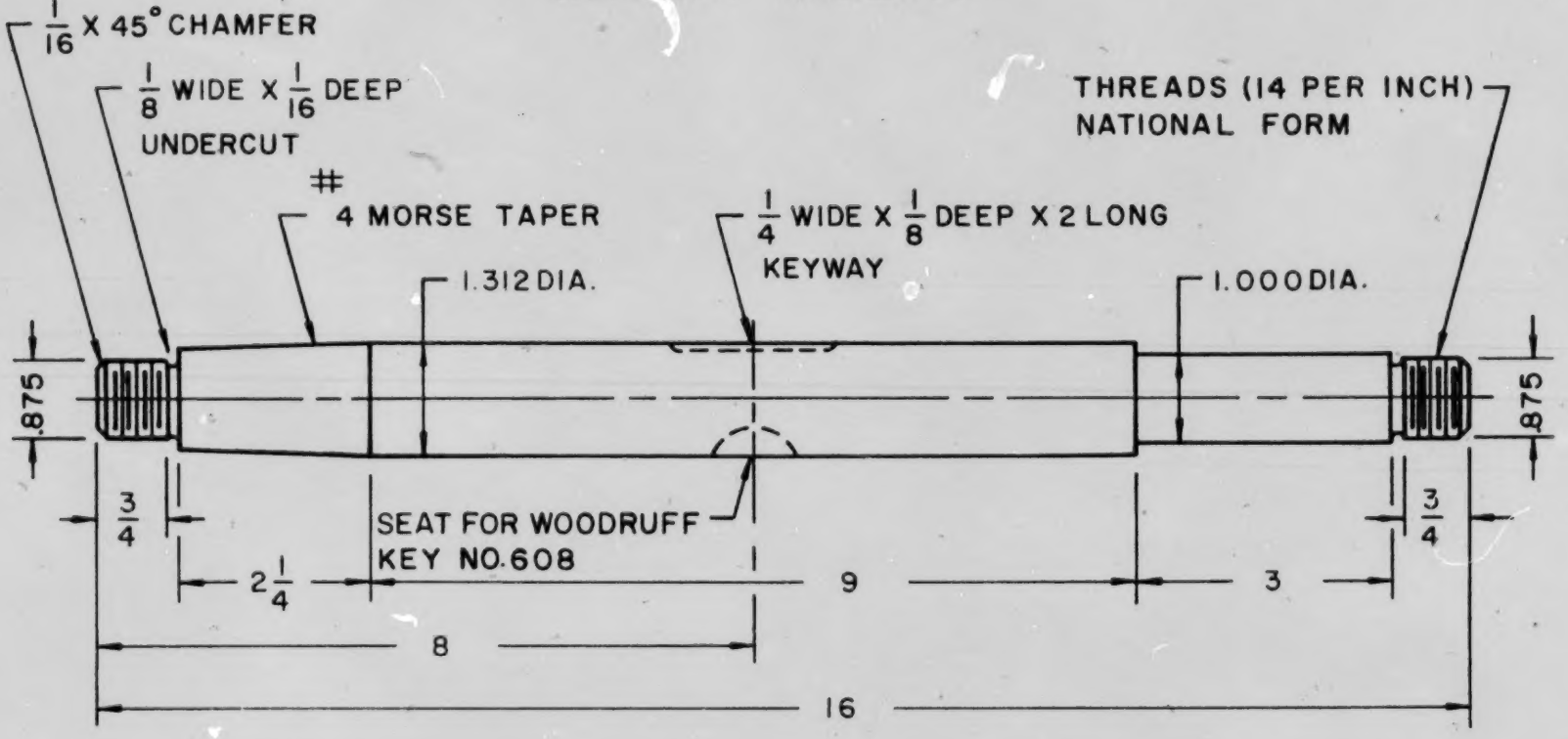
LOCATION OF THE CUTTER in relation to the center of round work piece can be established by either of these methods

MACHINE OPERATIONS

HORIZONTAL MILLING

JOB NO.5

KEYWAY MILLING



SCALE: $\frac{1}{2}$" = 1"

HORIZONTAL MILLING MACHINE PROJECT JOB NO. 6

STRADDLE MILLING

OBJECTIVE: Be able to use two cutters at the same time.

STOCK: C.R.S.

TOOLS: Vise (plain), 1-2" micrometer, side milling cutters, 4" O.D. (2), depth micrometer, and file.

STEPS:

1. Cut piece on saw as per drawing.
2. Mill piece to size with plain cutter.
3. Remove cutter.
4. Straddle mill 1" size.
5. Straddle mill 1/2" size.
6. Remove burr with file.
7. Have job checked by instructor.

PROGRESS QUIZ:

1. Why should the two cutters be the same size (O.D.)?
2. Why should side milling cutters be used?
3. What safety precautions should be taken when using two cutters at the same time?
4. Why should the cutters rotate in the same direction?
5. How should the machinist care for his tools when making milling machine setups?

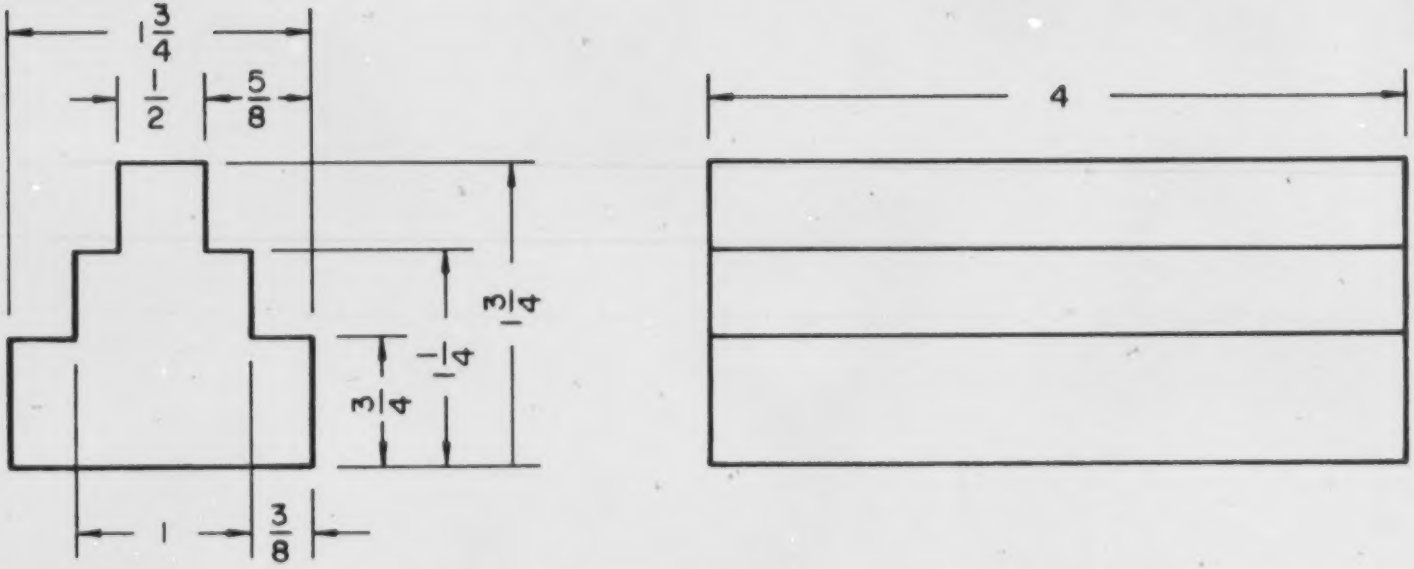
REFERENCES:

MACHINE OPERATIONS

HORIZONTAL MILLING

JOB NO.6

STRADDLE MILLING



SCALE : 1" = 1"

HORIZONTAL MILLING MACHINE PROJECT JOB NO. 7

GANG MILLING

OBJECTIVE: Be able to use three or more cutters at the same time.

STOCK: C.I.

TOOLS: Vise, side milling cutters, plain milling cutter, depth micrometer, micrometer, and file.

STEPS:

1. Cut piece as in drawing allowing for 1/4" oversize.
2. Mill piece to size as in drawing using plain milling cutter.
3. Remove plain milling cutter from arbor.
4. Set side milling cutter on arbor to mill job as in drawing.
5. Take first cut on scrap piece of metal.
6. Remove scrap piece, and start milling on regular piece.
7. Do not attempt to mill job in one cut.
8. Remove burrs.
9. Remove work, and have instructor inspect job.

PROGRESS QUIZ:

1. State the difference between straddle and gang milling.
2. Is gang milling the same as form milling?
3. Does gang milling require more setup time than straddle milling?
4. To what degree of accuracy can the milling machine use be aligned?
5. Explain what is meant by the feeds and speeds.
6. Explain the cutting action of a milling machine cutter.

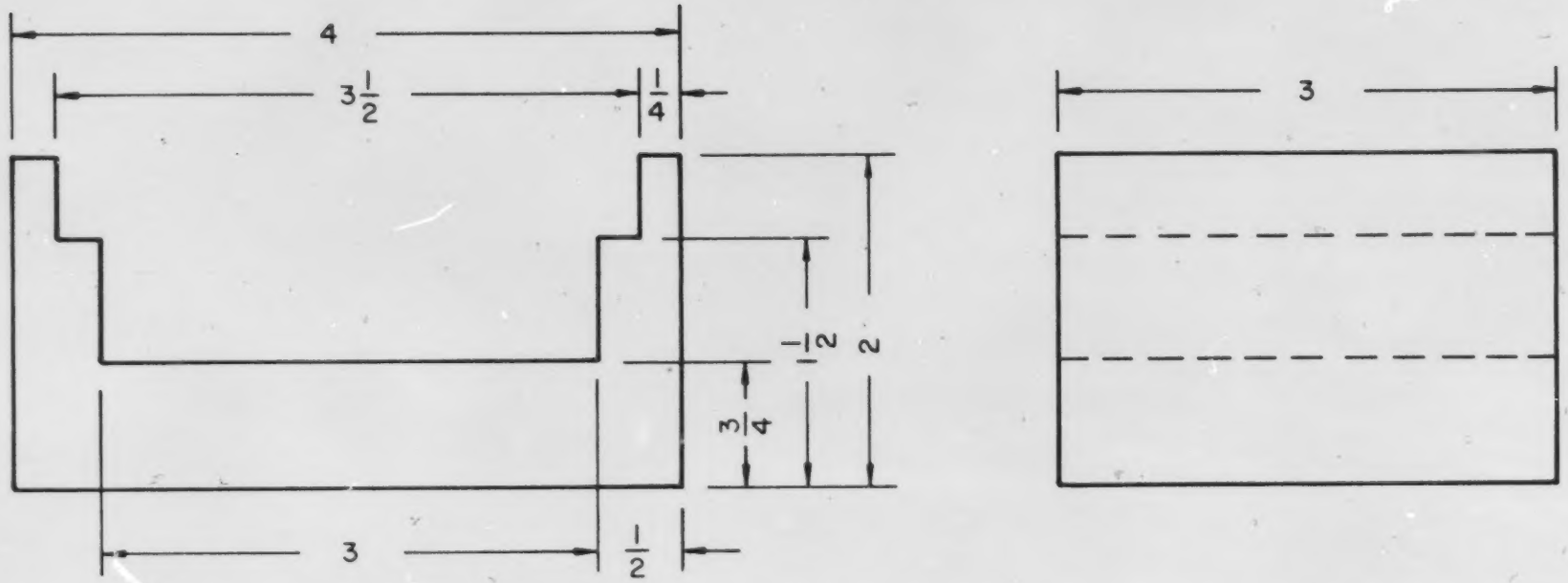
REFERENCES:

MACHINE OPERATIONS

HORIZONTAL MILLING

JOB NO.7

GANG MILLING



SCALE: 1" = 1"

HORIZONTAL MILLING MACHINE PROJECT JOB NO. 8A and 8B

SAW MILLING

OBJECTIVE: Be able to use a slitting saw with the work being clamped to the milling machine table.

STOCK: C.I.

TOOLS: Slitting saw, micrometer, strapping clamps, bolts and nuts, scale, file, and plain milling cutter.

STEPS:

1. Cut piece on saw allowing 1/8" on length and width.
2. Mill job to size as in drawing using plain milling cutter. Strap job to table.
3. Remove cutter from arbor and place saw on arbor.
4. Saw first piece to size -- 1.916".
5. Saw 2nd piece to same size as above.
6. Remove piece from table.
7. File burrs off edges.
8. Have Instructor inspect job.

PROGRESS QUIZ:

1. Why is climb milling important when using the slitting saw?
2. Why should the slitting saw be located over the T-slot of the table?
3. Does the slitting saw come with side chip clearance, and why or why not?
4. Why is the cutter thinner at the center than at the edge?
5. Is it proper to use the slitting saw for cutting slots in the heads of screws?

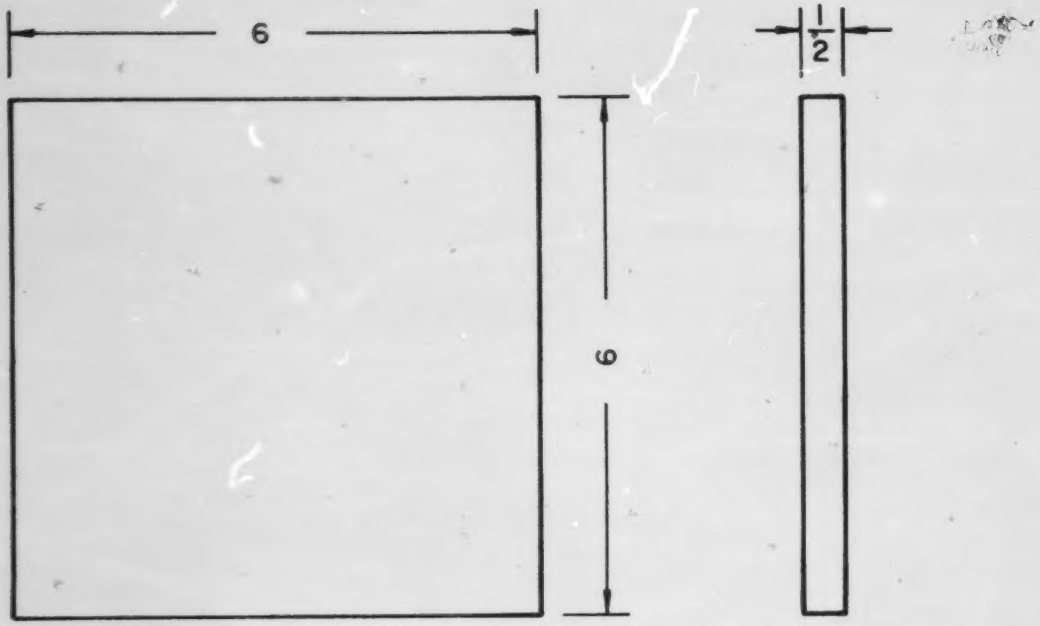
REFERENCES:

MACHINE OPERATIONS

HORIZONTAL MILLING

JOB NO. 8A

CLAMP MILLING

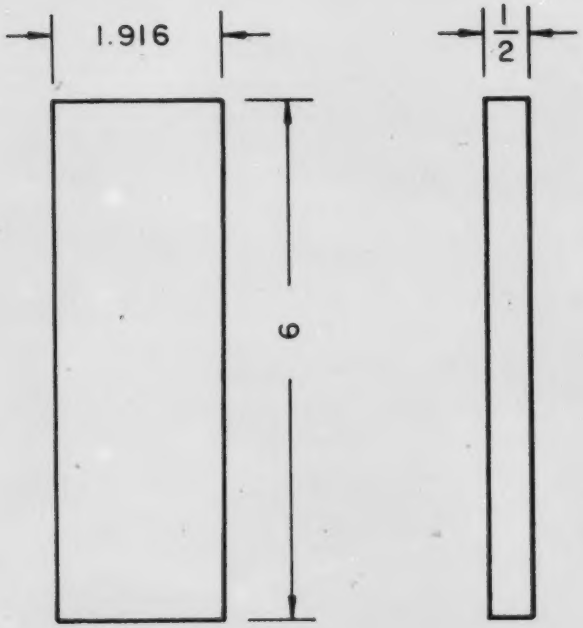


SCALE: $\frac{1}{2}" = 1"$

MACHINE OPERATIONS

HORIZONTAL MILLING

JOB NO.8B
SAW MILLING



SCALE: $\frac{1}{2}" = 1"$

HORIZONTAL MILLING MACHINE PROJECT JOB NO. 9A

PLAIN MILLING

OBJECTIVE: Be able to use plain indexing.

STOCK: C.R.S. 3" dia. x 2" long.

TOOLS: Plain milling cutter, index head, file, and micrometer.

STEPS:

1. Set dividing head on table and footstock. Handle carefully. Prevent injuries.
2. Center drill both ends and check centers for alignment.
3. Select right size cutter according to the work you are given to mill.
4. Check with instructor for information, and select proper spacing on Index Plate.
5. Mill largest square on a 3" dia. of stock x 2" stock.

PROGRESS QUIZ:

1. What is the largest size square from a 3" round stock?
2. What was the formula for indexing a square?
3. How much stock was milled from each side?
4. Is it safe to use a dull cutter? Explain your answer.
5. Could this job be done in a vise? Explain your answer.

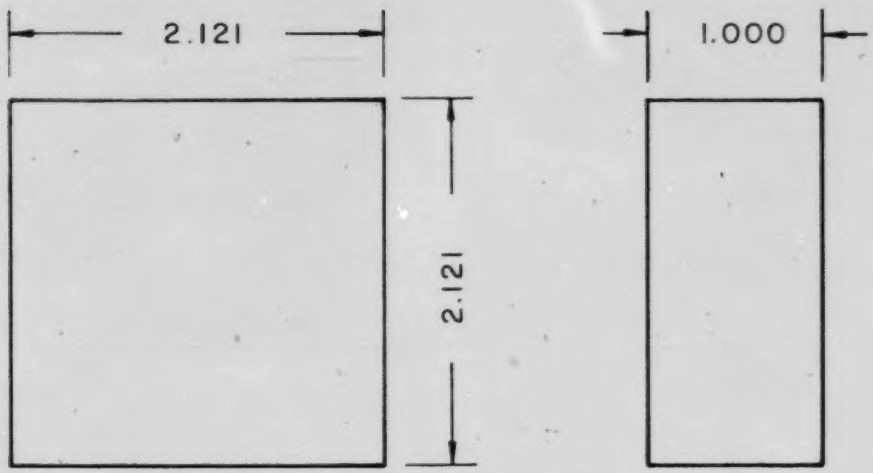
REFERENCES:

MACHINE OPERATIONS

HORIZONTAL MILLING

JOB NO. 9A

PLAIN MILLING



SCALE: 1" = 1"

HORIZONTAL MILLING MACHINE PROJECT JOB NO. 9B

PLAIN MILLING

OBJECTIVE: Be able to use plain indexing.

STOCK: C.R.S. -- 3" dia. x 2" long.

TOOLS: Plain milling cutter, index head, file, and micrometer.

STEPS:

1. Center drill both ends.
2. Check centers for alignment.
3. Use same cutter from Job 9A.
4. Check with Instructor for information, and select proper spacing on Index Plate.
5. Mill largest hexagon on a piece of stock 3" dia. x 2" long, and remove burrs.
6. Have job checked by your instructor.

PROGRESS QUIZ:

1. What is the largest hexagon from a 3" round stock?
2. What was the formula for indexing a hexagon?
3. How much stock was milled from each side?
4. What was the R.P.M. of the cutter?
5. Why was conventional milling used instead of climb milling?

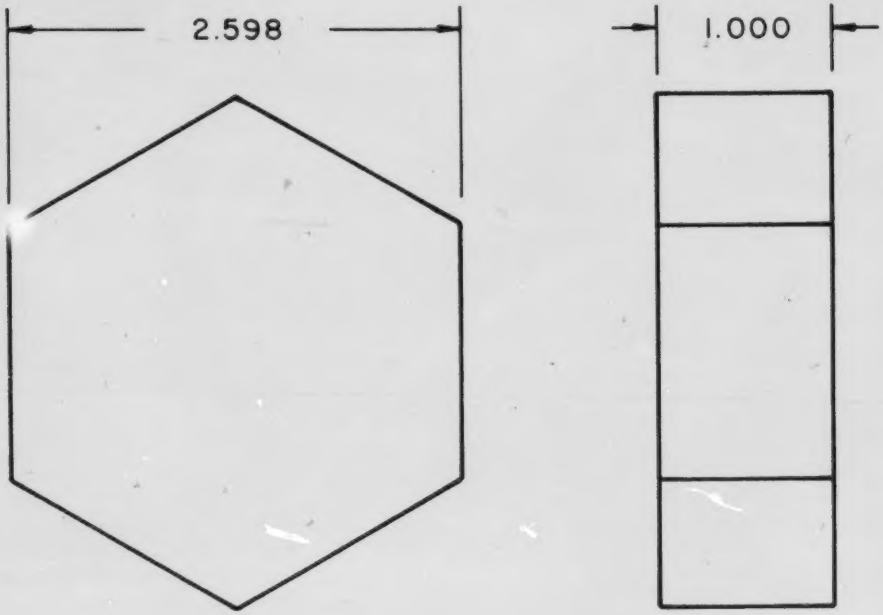
REFERENCES:

MACHINE OPERATIONS

HORIZONTAL MILLING

JOB NO. 9B

PLAIN MILLING



SCALE: 1" = 1"

HORIZONTAL MILLING MACHINE PROJECT JOB NO. 9C

PLAIN MILLING

OBJECTIVE: Be able to use plain indexing.

STOCK: C.R.S. 3" dia. x 2" long.

TOOLS: Plain milling cutter, index head, file, and micrometer.

STEPS:

1. Center drill both ends.
2. Check centers for alignment.
3. Use same cutter from Job No. 9B.
4. Check with Instructor for information, and select proper spacing on index plate.
5. Mill largest octagon on a piece of stock 3" dia. x 2" long.
6. Remove burrs.
7. Have job checked by your Instructor.

PROGRESS QUIZ:

1. What is the largest octagon on a 3" dia. round stock?
2. What was the formula for indexing an octagon?
3. How much stock was milled from each side?
4. Was steel ink used to lay out this job?
5. Find the number of turns of the crank for indexing five divisions.

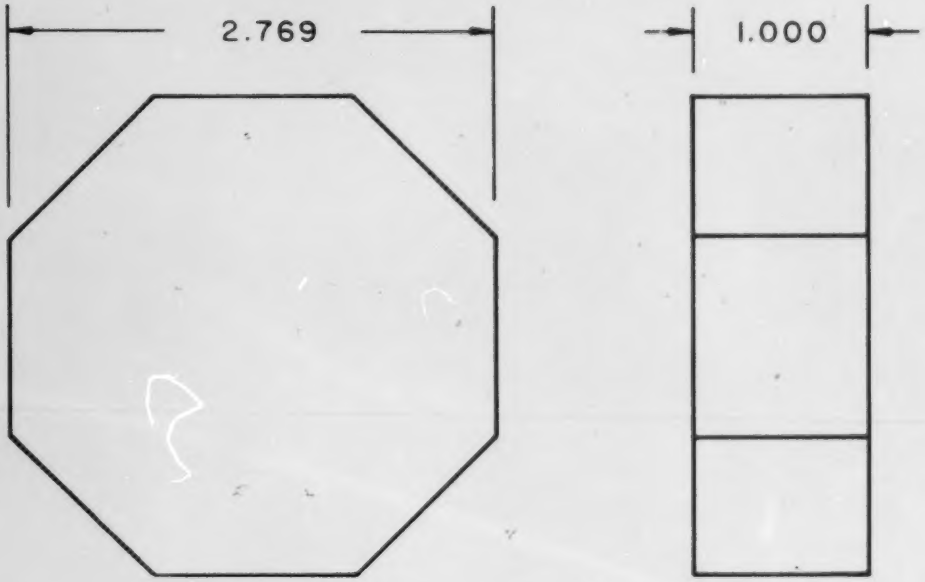
REFERENCES:

MACHINE OPERATIONS

HORIZONTAL MILLING

JOB NO. 9C

PLAIN MILLING



SCALE: 1" = 1"

HORIZONTAL MILLING MACHINE PROJECT JOB NO. 10

ANGULAR INDEXING

OBJECTIVE: Be able to do angle index milling.

STOCK: C.D.R. 3" x 3" long.

TOOLS: 1/8" milling cutter, file, scale, and protractor.

STEPS:

1. Center drill both ends of the stock.
2. Place dog on stock.
3. Place between index lead and foot stock.
4. Locate center of stock.
5. Mill first groove and continue to mill the other 5 grooves.
6. Remove burrs.
7. Remove job, and have job checked by Instructor.

PROGRESS QUIZ:

1. Determine the indexing for the following equally spaced divisions: 9^{o}, 18^{o}, 36^{o}, 45^{o}, and 54^{o}.
2. How many degrees are in a circle?
3. How many degrees does one complete turn of the index crank revolve the work?
4. How many minutes are in a degree?
5. How many degrees does one complete revolution of the spindle revolve the work?

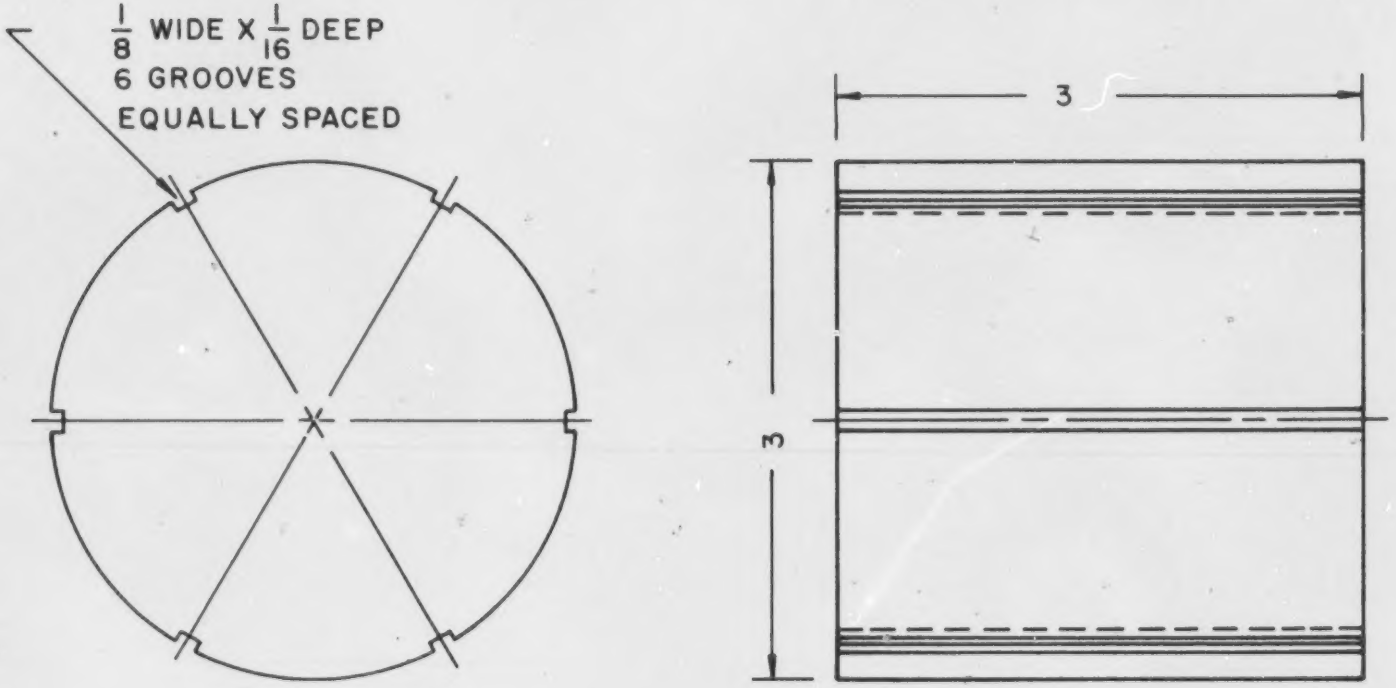
REFERENCES:

MACHINE OPERATIONS

HORIZONTAL MILLING

JOB NO. 10

ANGLE INDEX MILLING



SCALE: 1" = 1"

HORIZONTAL MILLING MACHINE PROJECT JOB NO. 11

PLAIN INDEXING

OBJECTIVE: Be able to cut a spur gear (6 pitch gear).

STOCK: Cast Iron (C.I.)

TOOLS: Casting as per drawing, drill, reamer, mandrel, No. 4 gear cutter, and index head.

STEPS:

1. Press gear blank on mandrel using an arbor press.
2. Mount index centers on milling machine table.
3. Mount milling cutter, 6 pitch No. 4, on machine arbor.
4. Set index head for correct indexing.

   $\frac{40}{30}$ = 1-1/3 turns

   $1/3 \times \frac{10}{10} = \frac{10}{30}$

   Index 1 turn and 10 holes on a 30-hole circle.
5. Place dog on large end of mandrel, and mount mandrel and job between centers with dog toward the head stock.
6. Clamp tail of dog in slot so dog will not force out of position.
7. Centralize the cutter with the gear blank.
8. Run the work under the cutter, and raise the table slightly.
9. Move job clear of cutter.
10. Rough out the first tooth, and continue to cut other teeth.
11. The following information relates to the gear that you are about to cut:

Pitch - 6"	Dedendum - .1928"
Outside Dia. - 5.3335"	Clearance - .0261"
Pitch Dia. - 5.000"	Working Depth - .3334"
Number of Teeth - 30	Tooth Form - $14\frac{1}{2}^{o}$
Whole Depth - .3595"	
Circular Pitch - .5236"	
Addendum - .166"	

PROGRESS QUIZ:

1. Why must the index centers be in line?
2. How will you arrange the sector?
3. How much stock do you leave for a finish cut?
4. Why was a No. 4 gear cutter used?
5. Why are screws provided to clamp the tail of the dog?
6. Write an Operation Sheet for an 8-pitch, 24-tooth gear (spur).

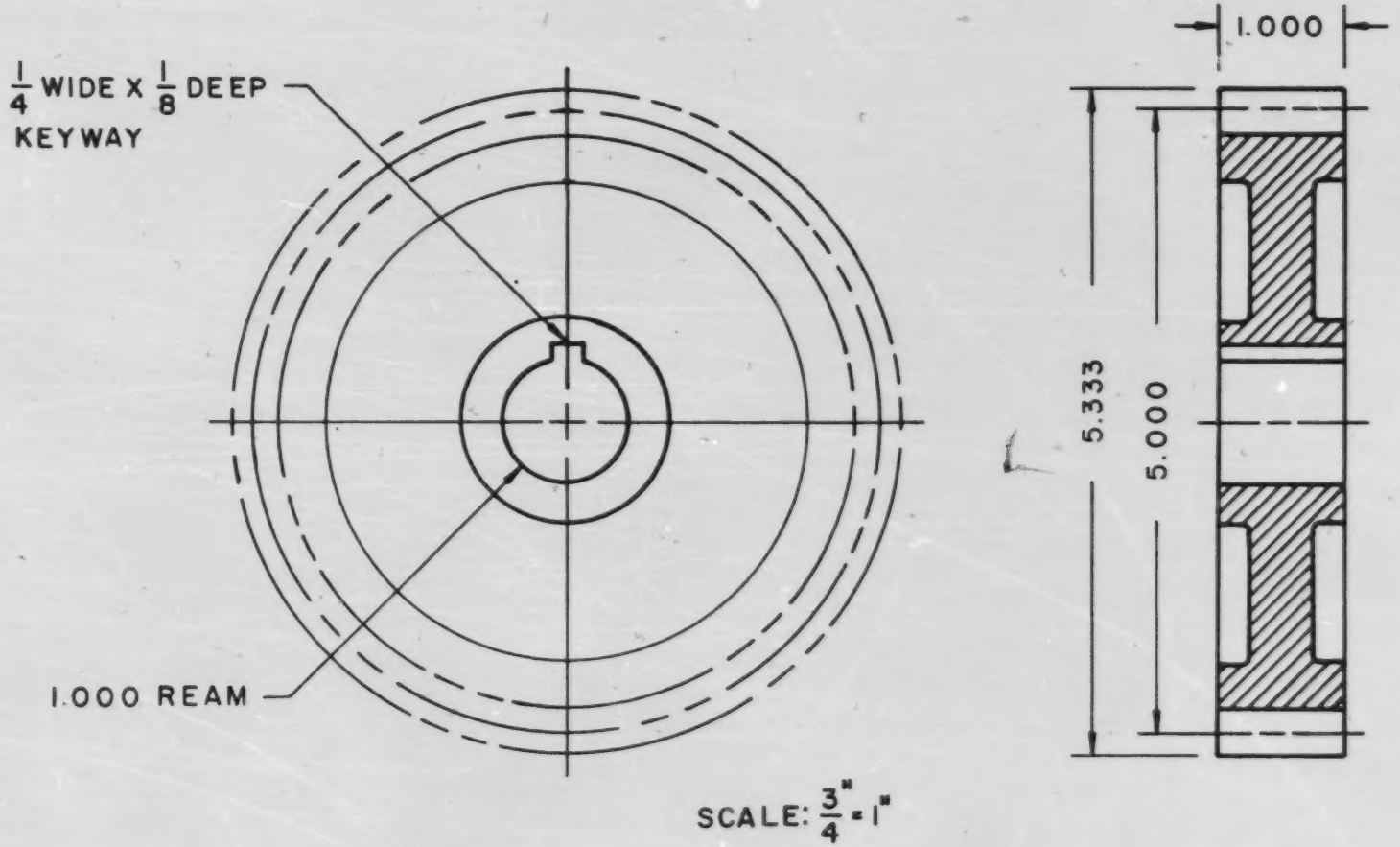
REFERENCES:

MACHINE OPERATIONS

HORIZONTAL MILLING

JOB NO.11

SPUR GEAR MILLING



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HORIZONTAL MILLING MACHINE PROJECT JOB NO. 12

RACK GEAR

OBJECTIVE: Be able to cut a rack gear.

STOCK: Cast Iron (C.I.)

TOOLS: No. 4 gear cutter, casting 6" long x 1½" wide, and plain vise.

STEPS:

1. Use same cutter as in previous job.
2. Set casting in vise.
3. Rough out first tooth by going in with the table to the required measurement.
4. Take four roughing cuts and 1 finish cut to the required depth.
5. When job is complete, have the Instructor check it.

PROGRESS QUIZ:

1. State the difference between a rack gear and a spur gear.
2. The linear pitch of a rack gear is the same as a _____ pitch of a spur gear.
3. What is the function of a rack gear?
4. Where is the rack gear located on a South Bend lathe.
5. Write an Operation Sheet on cutting a rack gear (8 pitch).

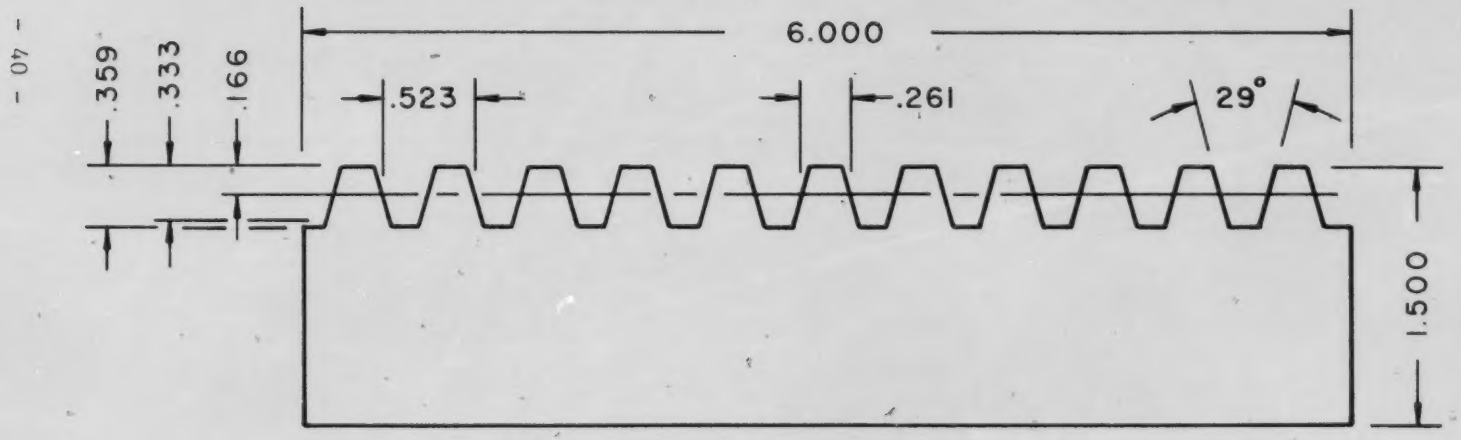
REFERENCES:

MACHINE OPERATIONS

HORIZONTAL MILLING

JOB NO. 12

RACK GEAR MILLING

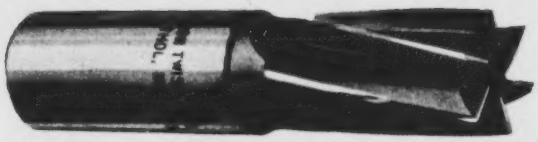


SCALE: 1" = 1"

On Vertical machines, the spindle is located vertically, parallel to the column face, and is mounted in a sliding head that can be fed up and down by hand or power. Some machines are designed so the entire head can also be swiveled to permit working on angular surfaces. These machines do not have overarms or braces, but otherwise are similar in operation to horizontal machines.

Vertical milling attachment which may be mounted on the face of the column of the overarm enables a plain or universal milling machine to be used as a vertical milling machine.

A vertical attachment enables the horizontal milling machine to be used for such operations as face milling, end milling, drilling, boring, and T-slot milling.

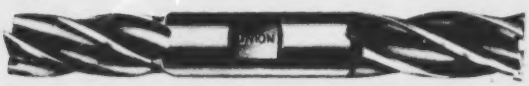


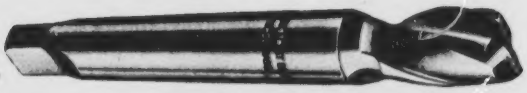
Straight-shank spiral end mill. (Union Twist Drill Co.)

Milling machine standard tapered shank end mill. (Brown & Sharpe Mfg. Co.)

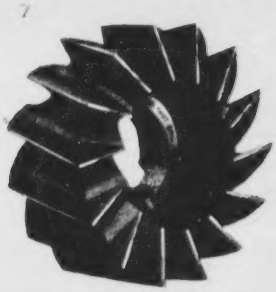
Spiral end mill with Brown & Sharpe tapered shank. (Brown & Sharpe Mfg. Co.)

Spiral double-end mill. (Union Twist Drill Co.)



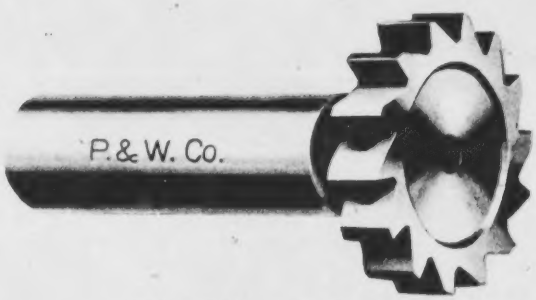


Two-lipped tapered shank end mill. (Union Twist Drill Co.)



Shell end mill. (Union Twist Drill Co.)

T-slot cutter. (Union Twist Drill Co.)



Woodruff key-seat cutter. (Pratt & Whitney Co.)

1. End Milling Cutter -- Have straight or helical teeth on the circumference, and straight teeth on one end. Serve for milling slots and facing or profiling narrow surfaces.

2. Two-Lipped End Mill -- Also known as slotting mills. Have only two teeth on the circumference, and the end teeth are cut to center.

3. Shell End Mill -- Made in larger sizes than plain end mills. Recessed on the face to receive a screw or nut for mounting. On a separate shank or stub arbor driven by keys on the spindle nose.

4. Inserted Tooth Face Mill -- Face milling cutters are larger than end mills. Face mills are used for milling large flat areas. Face milling cutters are over 6" in diameter and have inserted teeth held in place by a wedging device.

5. T-Slot Cutter -- Similar to keyway cutters, but made with staggered teeth and side cutting faces. Specifically for forming T-slots. After a straight slot has been cut in the work with a side mill, the cutter shank enters to mill that part of a standard T-slot that receives the head of a T-bolt.

6. Woodruff Keyway Cutter -- Have profile teeth, and made in both shank and arbor types. Used for cutting semi-circular keyways in shaft.

7. Dovetail Cutter -- Similar to a single angle milling cutter with an integral shank. Used to form the sides of a dovetail after the tongue or the groove has been machined with another suitable cutter. Dovetail cutters may be obtained with 45°, 50°, 55°, or 60° angles.

8. Flycutter -- Single pointed cutting tool with the cutting end ground to a desired shape. Since all the cutting is done with one tool, a five feed must be used.

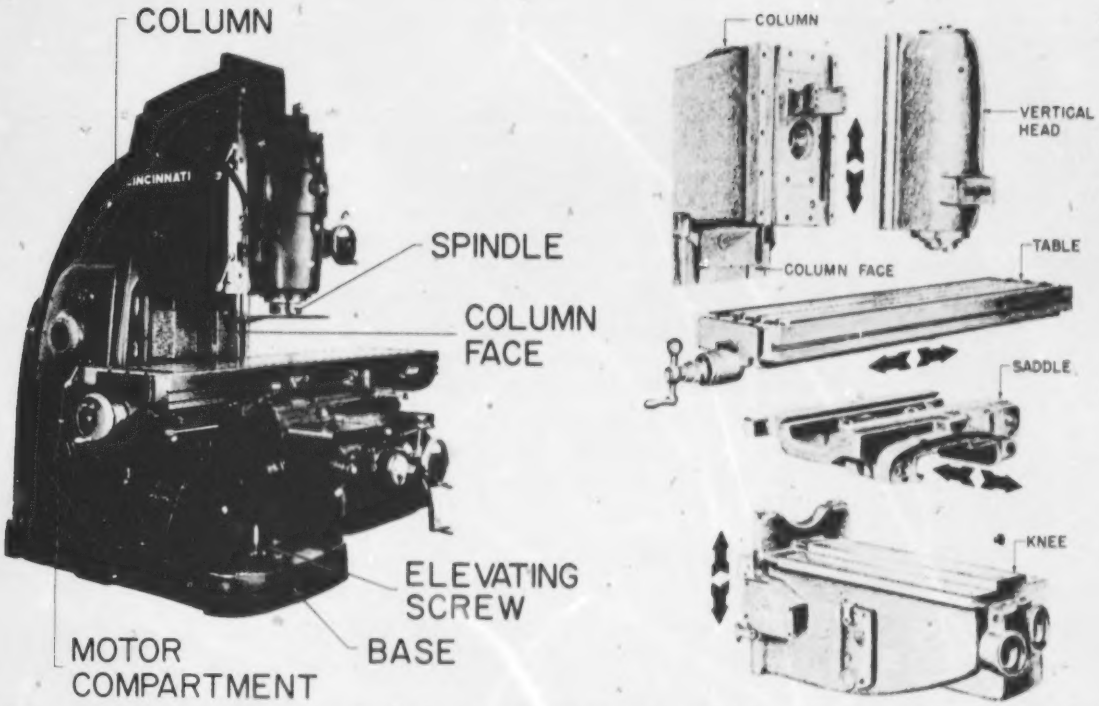


FIG. Main elements of the vertical knee-and-column type milling machine. (The Cincinnati Milling Machine Co.)

VERTICAL MILLING MACHINE PROJECT JOB NO. 1

KEYWAY MILLING

OBJECTIVE: Be able to use an end mill.

STOCK: C.R.S. (Cold Roll Steel)

TOOLS: Vise, 3/16" end mill cutter, scale, depth gage, and file.

STEPS:

1. Set 3/16" cutter (end mill) in machine.
2. Lay out front with steel ink and lay out vertical and horizontal line.
3. Place object in vise and extend over vise so square can be planed.
4. Find center of shaft.
5. Follow instruction of blueprint, and start to mill.
6. Do not remove too much stock at one time, because of thin end mill.
7. Remove project, and have Instructor check for size.

PROGRESS QUIZ:

1. What is the difference between a 2-lip and a 4-lip end mill?
2. How was the center of the shaft located?
3. Name two ways used to square a vise.
4. Explain the difference between a straight and a taper shank end mill.
5. Name four different kinds of steel from which an end mill is made.

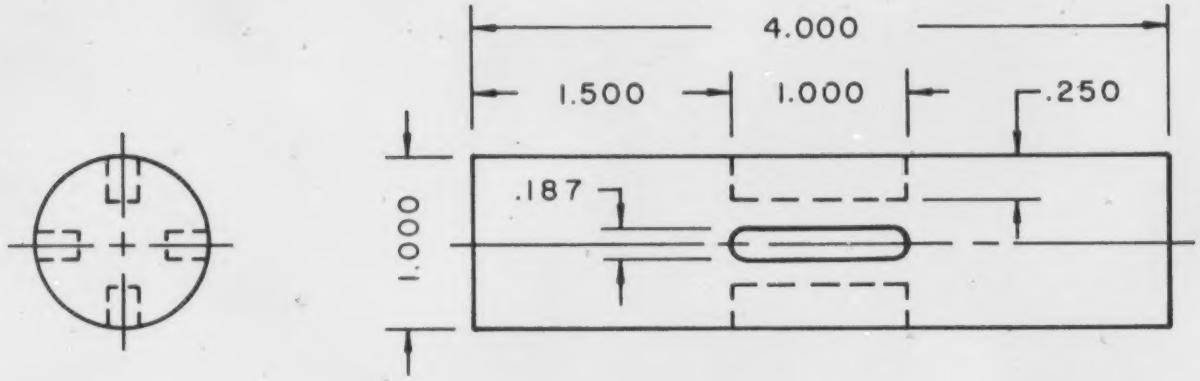
REFERENCES:

MACHINE OPERATIONS

VERTICAL MILLING

JOB NO. 1

KEYWAY MILLING



SCALE: 1"=1"

VERTICAL MILLING PROJECT JOB NO. 2

T-SLOT MILLING

OBJECTIVE: Be able to use a T-slot cutter.

STOCK: C.D.S. (Cold Drawn Steel)

TOOLS: Vise, T-slot cutter, 3/4" end mill, scale, and file.

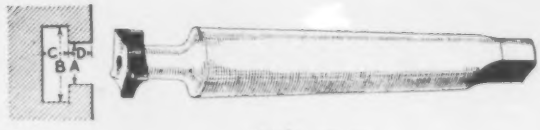
STEPS:

1. Set piece in vise.
2. Use 3/4" end mill to mill opening.
3. Remove 3/4" end mill, and attach T-slot cutter.
4. Remove stock with T-slot cutter as in drawing.
5. Remove small amount of metal because of cutter.
6. File burrs.
7. Remove project, and check with Instructor.

PROGRESS QUIZ:

1. Why was the 3/4" end mill used first?
2. On what type of machines are T-slots found in the shop?
3. What is the purpose of a T-slot?
4. Does a T-slot cutter have side milling teeth?

REFERENCES:



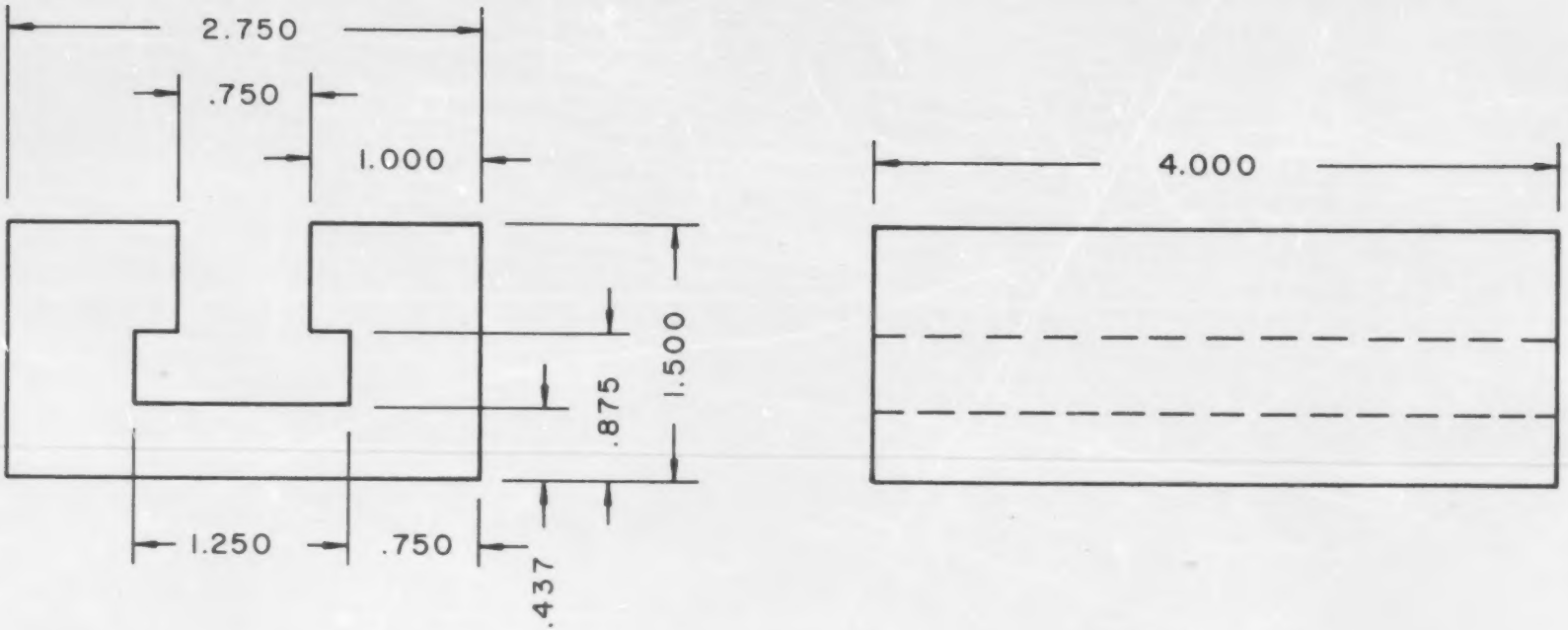
T-slot cutter.

MACHINE OPERATIONS

VERTICAL MILLING

JOB NO.2

T-SLOT MILLING



SCALE: 1" = 1"

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VERTICAL MILLING PROJECT JOB NO. 3

SHELL END MILLING

OBJECTIVE: Be able to use a shell end mill cutter.

STOCK: Cast Iron (C.I.)

TOOLS: Vise, micrometer, steel ink, square, scale, and file.

STEPS:

1. Blue ink front of bar, and lay out horizontal and vertical lines.
2. Place shell end mill in machine.
3. Place stock in vise, and check for squareness.
4. Line horizontal line parallel with square head.
5. Remove metal on one side of square.
6. Continue operation until square is milled.
7. Remove piece from vise, and file edges.
8. Have Instructor check project.

PROGRESS QUIZ:

1. What formula was used to find the square to be milled?
2. State the difference between a two-lip end mill and a shell end mill.
3. What is the largest square to be milled from 2" diameter stock?
4. What way is more accurate to do this job -- in a vise or index head?
5. What was the purpose of putting blue ink in front of the stock?

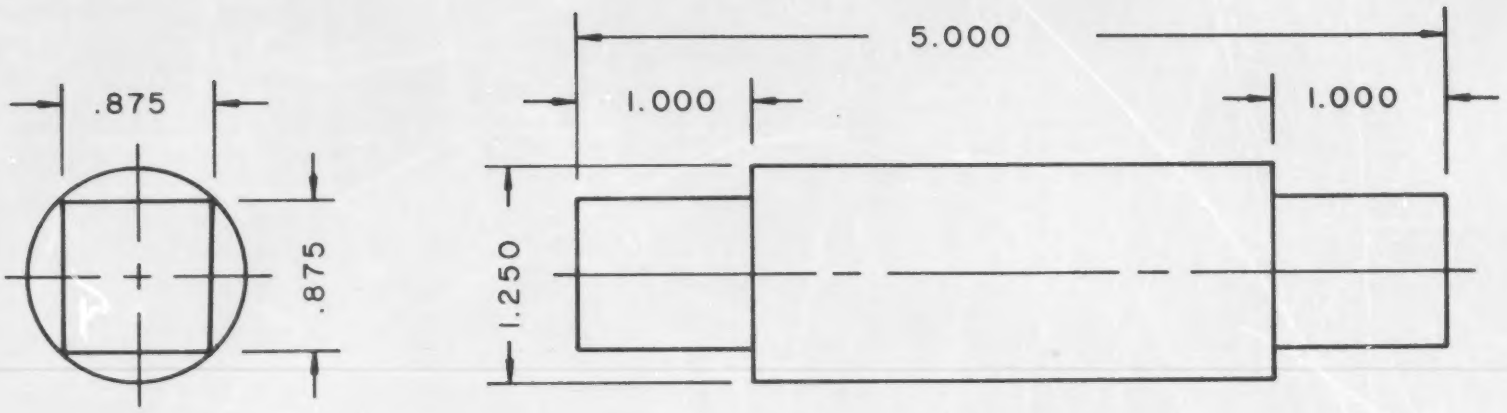
REFERENCES:

MACHINE OPERATIONS

VERTICAL MILLING

JOB NO.3

SHELL END MILLING



- 50 -

SCALE: 1" = 1"

VERTICAL MILLING MACHINE PROJECT JOB NO. 4

DOVETAIL MILLING

OBJECTIVE: Be able to use a 60° dovetail cutter.

STOCK: C.I. (Cast Iron)

TOOLS: Vise, protractor, scale, 60° dovetail cutter, file, micrometer, depth micrometer, end mill cutter and layout ink.

STEPS:

1. Indicate vise for squareness.
2. Set work in vise.
3. Use end mill cutter to make 1¼" opening, and mill to .540.
4. Remove cutter, and place 60° dovetail cutter in spindle.
5. Mill angle to required depth.
6. File all sharp edges.
7. Remove stock, and have Instructor check as per blueprint.

PROGRESS QUIZ:

1. Name the four angles that may be obtained with a dovetail cutter.
2. Does a dovetail cutter have any side teeth?
3. Are the T-slot cutter and the dovetail cutter the same? Explain your answer.
4. Why is it important for your vise to square when cutting a dovetail?
5. Name one part of a lathe where a dovetail is used.

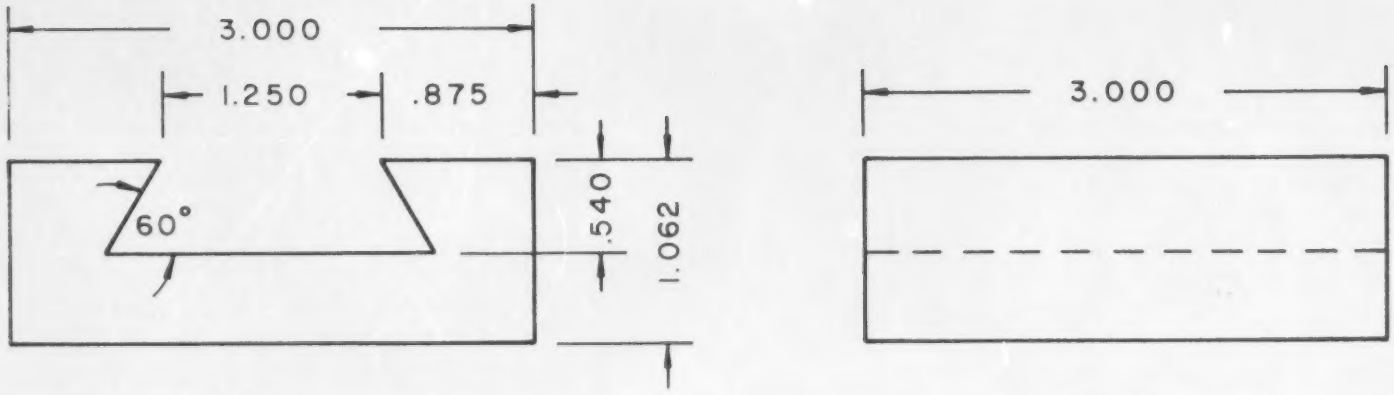
REFERENCES:

MACHINE OPERATIONS

VERTICAL MILLING

JOB NO.4

DOVETAIL MILLING



SCALE: 1" = 1"

VERTICAL MILLING MACHINE PROJECT JOB NO. 5

DRILLING

OBJECTIVE: To drill with the stock being in a vise instead of in an index head.

STOCK: Aluminum

TOOLS: Vise, 1/2" drill, dividers, steel ink, centerpunch, hammer, and drill chuck.

STEPS:

1. Lay out project as in drawing.
2. Center punch where holes are to be drilled.
3. Set drill in drill chuck.
4. Center drill hole.
5. Remove center drill, and place 1/2" drill in drill.
6. Drill hole to required depth.
7. Remove project from vise.
8. Have Instructor check project.

PROGRESS QUIZ:

1. Why is a universal vise used instead of a plain vise?
2. State the formula for finding the circumference of a circle.
3. What is the advantage of using a drill chuck instead of a collet for mounting a drill in the vertical milling machine.
4. Is a straight shank or a taper shank drill held in a drill chuck?
5. Is it more practical to do this job with an index head or a vise? Explain your answer.

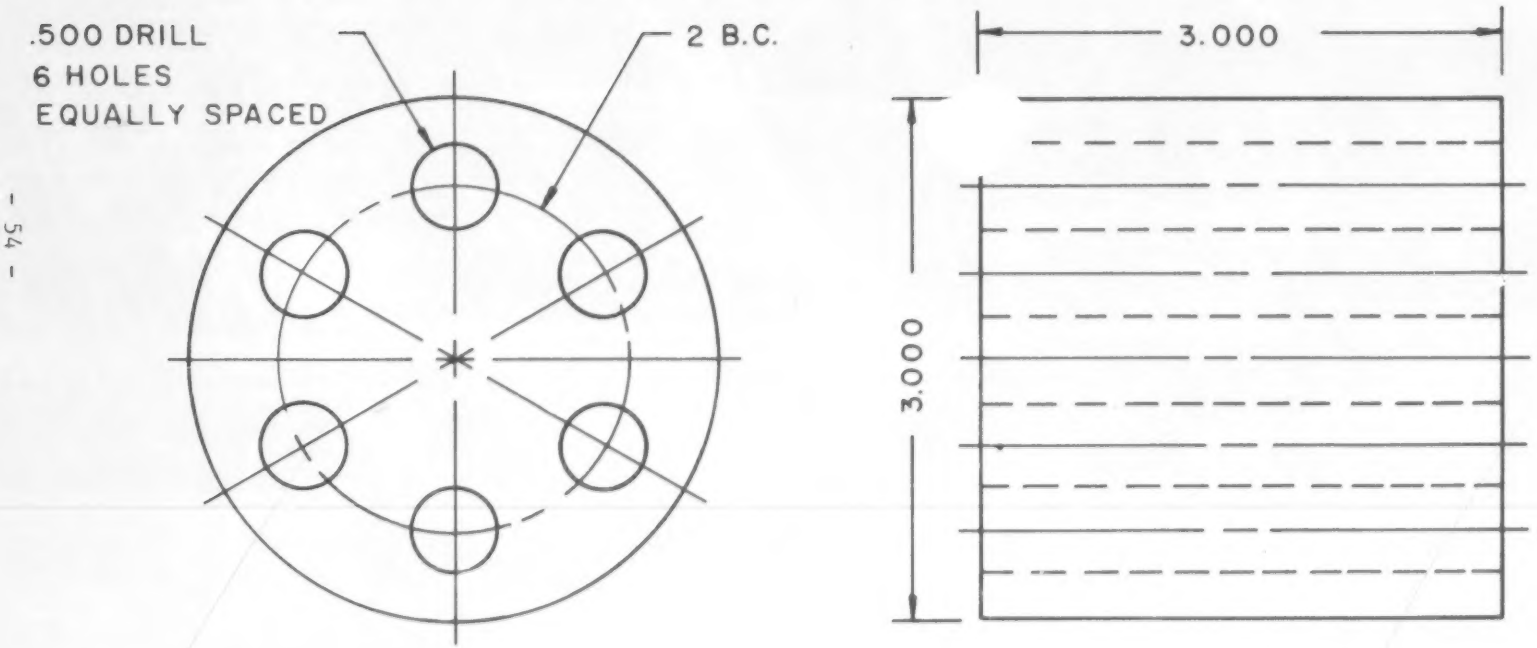
REFERENCES:

MACHINE OPERATIONS

VERTICAL MILLING

JOB NO.5

DRILLING



SCALE: 1" = 1"

VERTICAL MILLING MACHINE PROJECT JOB NO. 6

BORING

OBJECTIVE: Be able to bore on the vertical milling machine.

STOCK: C.I. (Cast Iron) 2" I.D.

TOOLS: Vise, boring tool (adjustable), tool bit, inside micrometer, scale, and file.

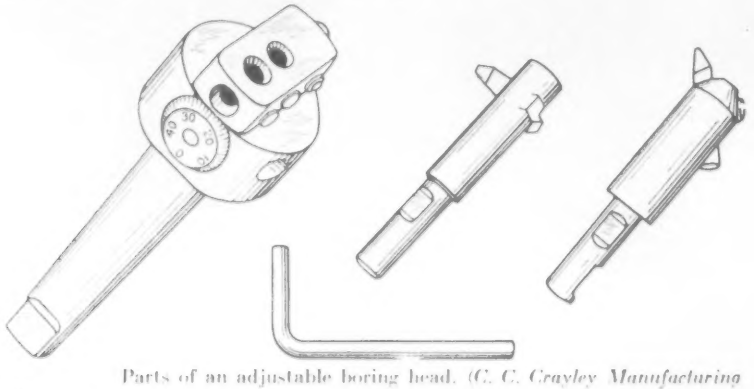
STEPS:

1. Place object in vise, and center object.
2. Place boring tool in spindle.
3. Bore to 2.125
4. Bore to 2.250
5. Bore to 2.375
6. Bore to 2.500
7. Bore to 2.625
8. Bore to 2.750
9. Instructor is to check each operation.

PROGRESS QUIZ:

1. Should the roughing tool bit be used for the finishing cut?
2. Explain the operation of boring.
3. How many thousands of an inch is the adjusting dial graduated?
4. State the difference between reaming and boring.

REFERENCES:



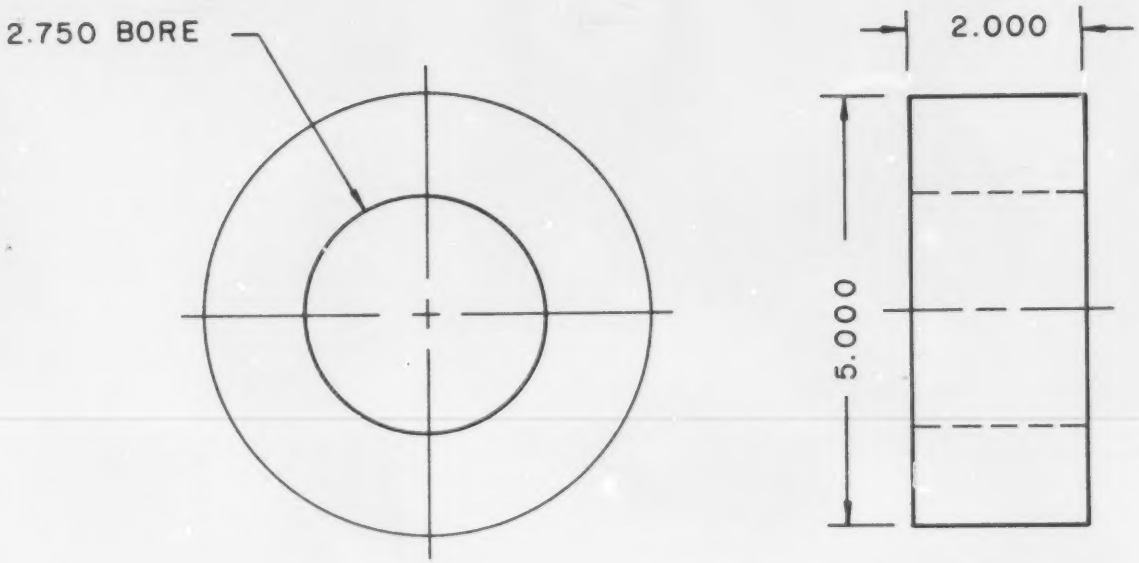
Parts of an adjustable boring head. (*C. C. Crayley Manufacturing Company*)

MACHINE OPERATIONS

VERTICAL MILLING

JOB NO. 6

BORING

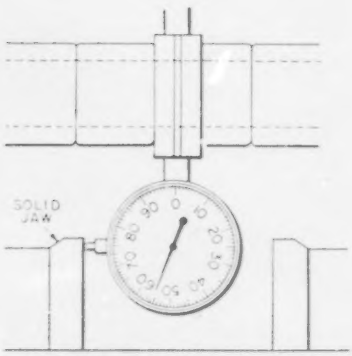


SCALE: $\frac{1}{2}" = 1"$

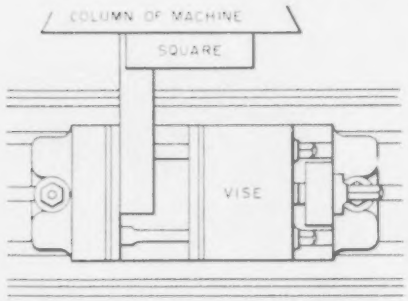
The following steps must be taken in order for the machines to last a long time.

1. Machines must be kept clean at all times.
2. Machines need proper oiling.
3. Care must be taken of tools.
4. Always use a mallet instead of a hammer when hitting is applied.
5. Always place a wooden board on table so that tools can be kept sharp.
6. When starting the machine, make sure you don't hear unusual noises.
7. Use proper guards when operating the machine.
8. Remove all burrs, chips, and dirt from the surface of the table.
9. Insert the key to prevent cutter slippage.

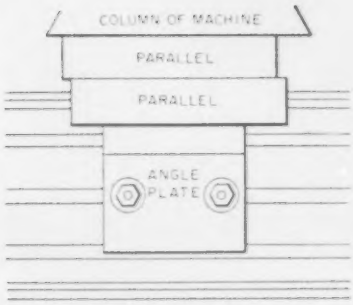
The following illustrations show three ways of aligning the vise with the milling machine.



ALIGNING VISE WITH INDICATOR

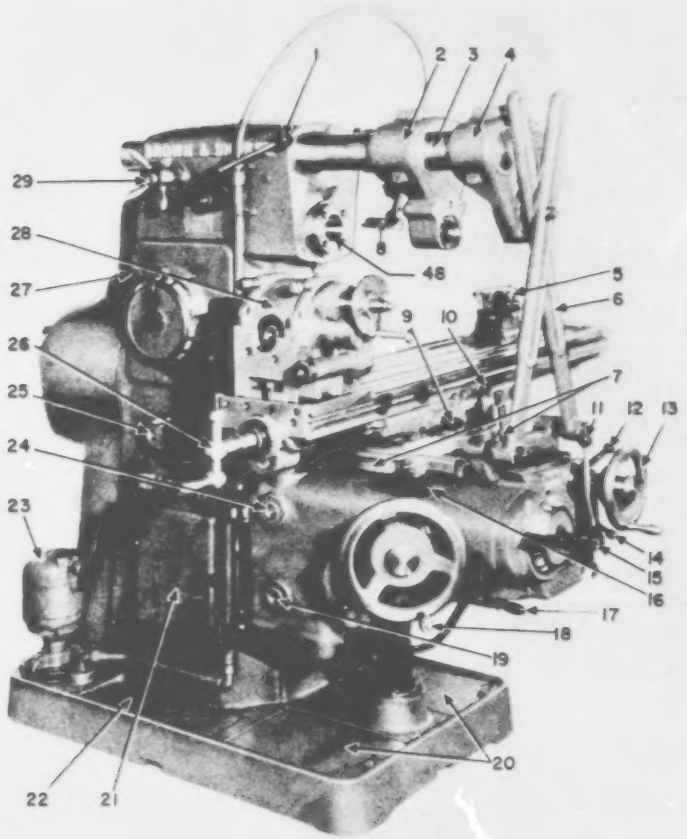


ALIGNING VISE WITH SQUARE



ALIGNING VISE WITH PARALLELS

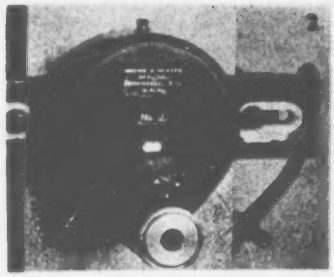
Instructions. The various parts of the Brown & Sharpe universal milling machine are numbered in the illustration shown. You are to write the number of each part listed in the space allowed. *Not all numbers shown are used in the test.*

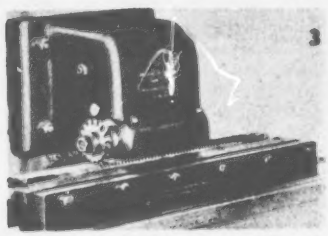


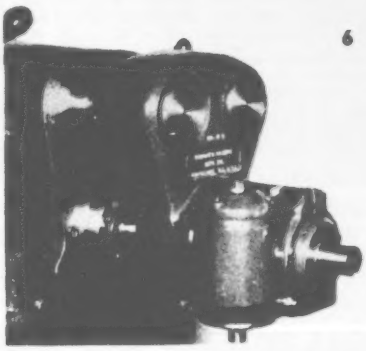
(1) Machine start and stop lever
( ) Vertical-adjustment handwheel
( ) Table-clamp lever
( ) Overarms
( ) Longitudinal-adjustment handwheel
( ) Overarm-clamp lever
( ) Saddle-clamp lever
( ) Transverse-adjustment handwheel
( ) Longitudinal-feed control lever
( ) Table-swivel clamp screw
( ) Vertical-feed control lever
( ) Feed-selector lever and dial
( ) Knee-clamp lever
( ) Coolant-reservoir cover plates
( ) Speed-selector lever and dial
( ) Spindle-motor reversing switch
( ) Outer-arbor yoke
( ) Coolant distributor
( ) Spindle
( ) Index head.

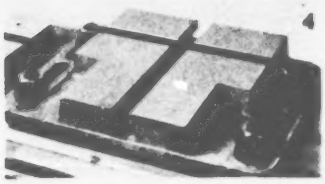
Shown below are nine milling-machine attachments. Each is numbered. You are to write the number of each attachment in the space allowed next to its name.

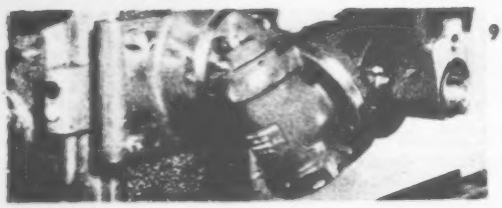
( ) Circular-milling attachment
( ) Universal-milling attachment
( ) Rack-milling attachment
( ) Index head and footstock
( ) Raising block
( ) Tilting table
( ) Vertical-milling attachment
( ) Slotting attachment
( ) High-speed milling attachment

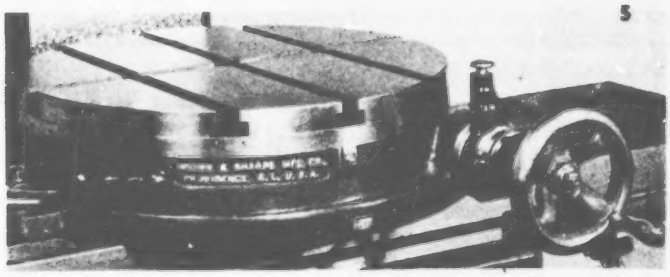












VERTICAL MILLING MACHINE PARTS TEST

Using the illustration match the numbers on the picture with their names. Write the number of each part in the space allowed next to its name.

( ) Spindle-feed handwheel

( ) Spindle-sleeve clamp lever

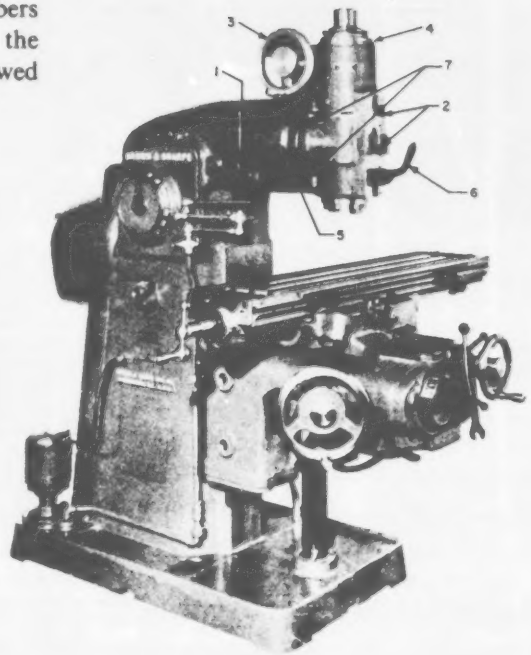
( ) Adjustable dial

( ) Vertical-alignment lever

( ) Clamp bolts

( ) Spindle stops

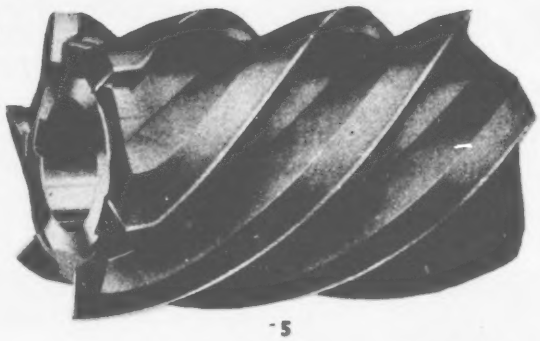
( ) Scale



Test

Match the names of the cutters shown by writing the number of each cutter in the space allowed before its name.

( ) Face mill
( ) Helical-arbor mill
( ) Inserted-tooth mill
( ) Helical-milling cutter
( ) Carbide tipped, shell end mill
( ) Woodruff
( ) End mill
( ) Corner-rounding right hand
( ) Convex
( ) T-slot
( ) Double-end mill
( ) Metal slitting cutter
( ) Concave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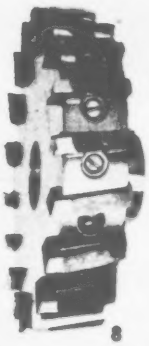
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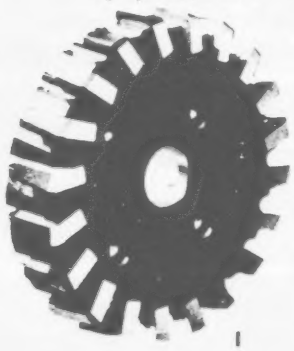
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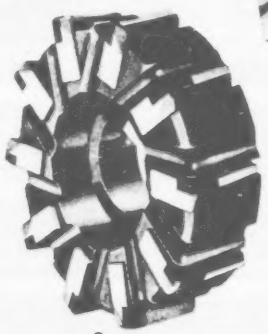
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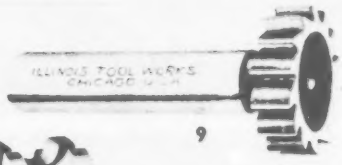
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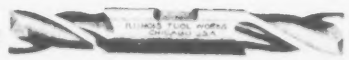
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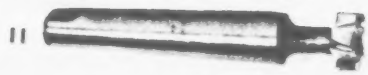
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